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6. AUTHOR(S)
Steven M. George

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Universal Technical Resource Services, Inc.
200 Valley Road, Suite 306
Mt. Arlington, NJ 07856

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13. ABSTRACT (Maximum 200 words)

This report covers the research and development undertaken by UTRS, Inc. in response to DoD STTR Topic 96T0004 Computer Aided Diagnosis & Treatment Display. UTRS developed a prototype Computer Aided Medical Assistant (CAMA) System that included the following functionality: Voice Recognition Software that records and displays patient data; voice-activated GPS positioning; development of a prototype PCMCIA card that interfaces to two (2) non-invasive sensors which in turn, interfaces to the CAMA System; research of Head Mounted Display (HMD) technology; integration of all the above into a functional, mobile, 2lb. flexible, wearable computer.

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COMPUTER-AIDED MEDICAL ASSISTANT (CAMA) SYSTEM

FINAL REPORT

CONTRACT DAAH04-96-C-0075

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FINAL REPORT
CONTRACT No. DAAH04-96-C-0075

1.0 OBJECTIVES

UTRS proposed to develop a Computer Aided Medical Assistant (CAMA) system in response to Topic Number: Army 96T004 - Computer Aided Diagnosis and Treatment Display. The Phase I CAMA system sought to accomplish the following objectives:

- Research and design a mobile, hardware and software diagnostic system that would be unobtrusive and efficacious for a field medic under battlefield conditions;
- Research and develop a voice recognition application that would allow the user to diagnose a patient in a hands free environment;
- Research, design, and develop an electronic breadboard (EB) capable of interfacing to non-invasive sensors;
- Research and integrate two non-invasive sensors into the EB that would, in turn, interface with the CAMA system;
- Research head mounted display (HMD) technology that would effectively display pertinent data under field conditions;
- Integrate and test all of the above into a self-contained, mobile, CAMA system.

2.0 ACCOMPLISHMENTS

2.1 A Mobile Hardware and Software Diagnostic System

UTRS proposed to use The Wearable™ as our hardware platform. The Wearable™ is a flexible 2 lb., 486-based, 75MHz, computer that is worn like a belt. It is equipped with 4 PCMCIA (PC Card) slots, 24MB RAM, 340MB disk space (via PC Card [510 MB optional]) and numerous other amenities that make it an excellent choice for field operations. The Wearable™ operates under the Windows 3.x or Windows95 operating system (our version uses Windows95).

Prior to our proposal for this effort, UTRS was already a value-added reseller (VAR) for The Wearable™; as such we already owned a unit and did not use STTR funds to purchase one under this contract. During the course of this effort, we did make suggestions to the manufacturer (Computing Devices International) for product design improvements that would enhance its adaptability and survivability under field conditions. Several of these recommendations were incorporated in the latest release of the product, including:

- A modular, hardened shell for improved durability;
- An improved BIOS that supports "hot swapping" of batteries;
- A 68 pin interface connector for improved configuration of peripherals;

- An exterior on/off switch and LED indicator.

In addition, a new version that incorporates a Pentium-class processor has been scheduled for release in 1Qtr97.

With the hardware platform chosen, we focused our efforts on the following five research areas: the CAMA application; the voice interface module; the design and fabrication of the electronic breadboard (EB); research of appropriate non-invasive sensors that could be interfaced with the EB; and research for an appropriate display device.

2.2 CAMA Application

2.2.1 Research

Prior to developing the CAMA graphical user interface (GUI), UTRS spoke with many potential users, including army and civilian medical personnel, doctors, nurses, and clinicians. The most dominant, recurring feedback was to keep the presentation of screen information to a minimum. Especially under field (or battlefield) conditions, where the user will be experiencing elevated levels of stress, and auditory and visual stimulation, a complex GUI could hinder rather than aid the user.

In the proposal for this effort, we had intended to create a database of information that would contain biographical data for sample patients. This information would include a soldier's benchmarked vital signs to be used as comparison for later test information. Under a field scenario, a medic would enter the downed soldier's dogtag number (via voice, barcode, etc.) and the database would retrieve the soldier's stored medical profile. The profile would display the benchmarked profile as well as pertinent medical information regarding the soldier's health conditions, such as allergies to certain medicines, etc. The medic would then enter the current vital sign information via voice, integrated non-invasive sensor, pen, or traditional method (keystroke, mouse). The intention being that the new information could be compared to the patient's benchmark to facilitate an intelligent diagnosis.

In our interviews however, military medical personnel suggested that this effort, although valuable, is not of paramount importance in the field, primarily because a field medic does not have sufficient time to perform these procedures. Other, more basic priorities were suggested. For example, a more important module would be one that reminds the medic to remember his A, B, Cs (airway, breathing, circulation). In times of stress, a medic may be so consumed with administering to a blatant affliction (e.g. stanching the flow of blood from a wound), that he overlooks a more critical emergency such as a blocked airway.

These (and other) valuable suggestions contributed to the prototype CAMA GUI and functionality.

2.2.1 Work Carried Out

The CAMA application was written in the Microsoft (MS) VisualC++ v4.2 programming language and its dialog editor. It is integrated with the Lernout & Hauspie (L&H) Voice Recognition Product (VRP) via a speech recognition Application Programming Interface (API) that interfaces with a UTRS-developed Dynamic Linked Library (DLL). Our DLL is written in pure C. The application resides on the desktop and is activated by clicking on the CAMA icon. An introduction is presented in text, accompanied by voice narration. Each paragraph is highlighted as the speaker narrates the introduction. The brief introduction explains the objective of the CAMA application and instructs the user to try it. At this point, the user can activate the program and navigate through the application solely by voice, or by voice, mouse, and/or keyboard.

2.2.1.1 Main Menu

The user is presented with a main menu as shown in Figure 2.2.1.1-1. From this screen, he can choose from the following options:

Selection	Result
• Patient Roster	Alphabetical listing of recently administered patients
• GPS	Activates GPS Module
• Libraries	Reserved for Medical Library Module
• Help	Reserved for Help Menu
• S.O.P.	Activates Standard Operating Procedures Module
• Vital Signs	Activates Interactive Vital Signs Module
• Patient Data	Alphabetical listing of recently taken vital statistics
• Exit	Exits CAMA system

2.2.1.2 Patient Roster

The Patient Roster window is shown in Figure 2.2.1.2-1. This module contains an alphabetical listing of patients that have recently been under the medic's care. The medic can tell CAMA the name of the listed patient and CAMA will retrieve the most recent medical information. To navigate, the user can say "down" or "up" to move the cursor one patient at a time, or "page down" or "page up" for the cursor to move one page at a time.

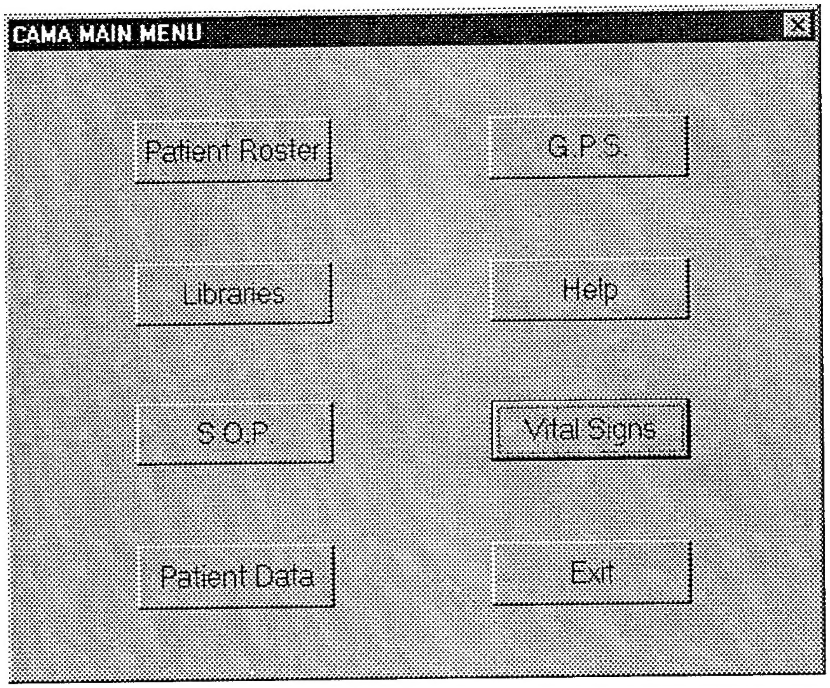


Figure 2.2.1.1-1 CAMA Main Menu

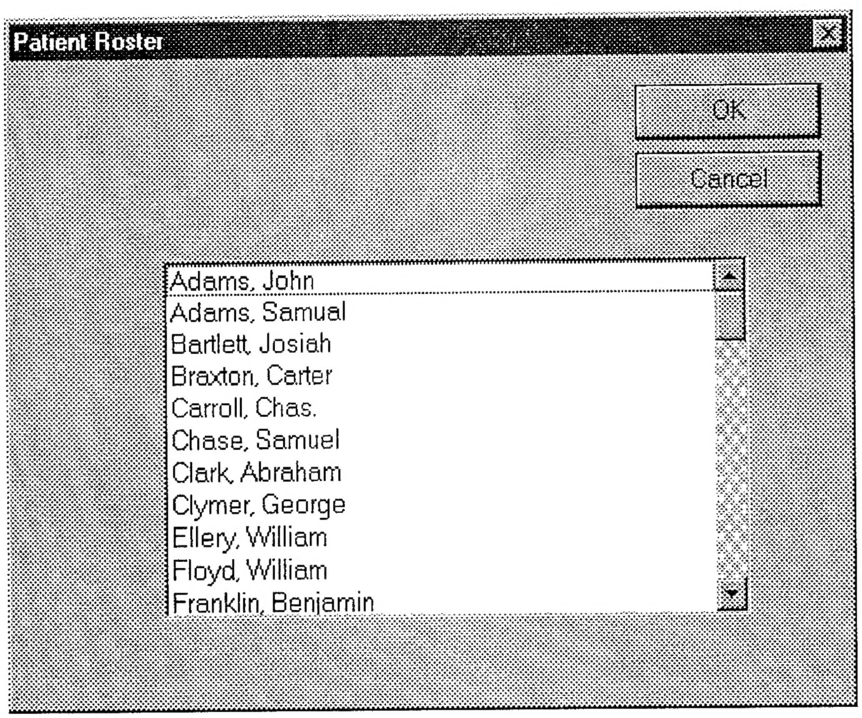
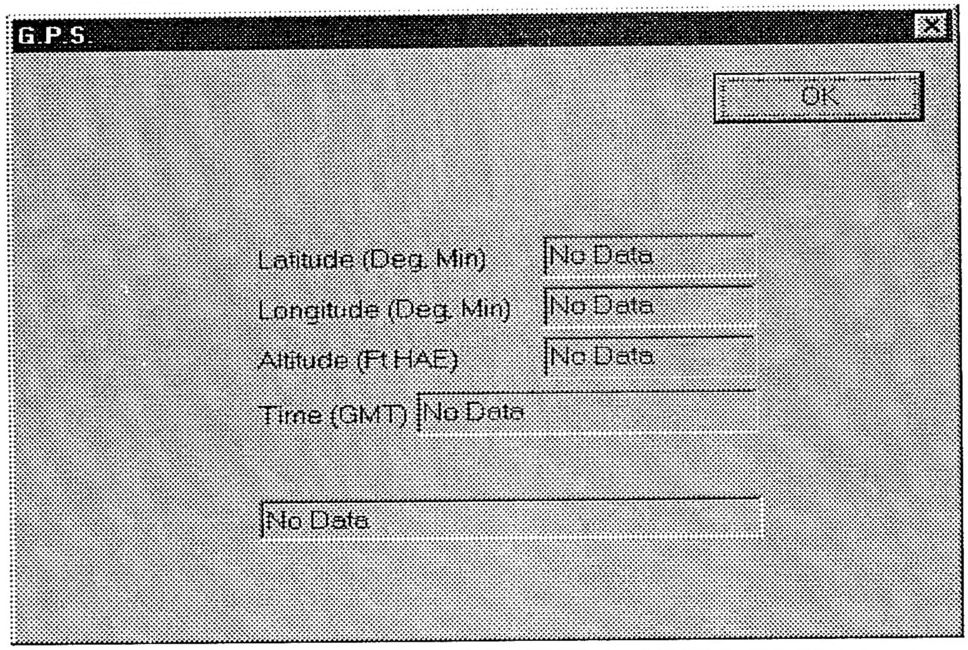


Figure 2.2.1.2-1 Patient Roster Module

2.2.1.3 GPS

The Global Positioning System (GPS) window is shown in Figure 2.2.1.3-1. The GPS Module activates the onboard Trimble Navigation GPS PC Card. GPS coordinates are taken by the Card which is tethered to a miniature antenna. The initial fix requires approximately ten (10) minutes and due to the inherent weakness of GPS signals, the antenna must be located outdoors to be operational. A recent, improved release of this card allows for rapid data acquisition after the initial fix has been taken, or if the receiver has been initialized with pertinent geographical data.



2.2.1.3-1 GPS Module

2.2.1.4 Libraries

The Libraries Module is not yet implemented. When activated from the main menu, a screen informs the user that it is currently unavailable. This module will contain medical protocols, drug dosages, and other academic information.

2.2.1.5 Help

The Help Module is not yet implemented. This module will contain general CAMA information as well as pertinent "how to" information to aid in the use of the CAMA system.

2.2.1.6 Standard Operating Procedures

The SOP window is shown in Figure 2.2.1.6-1.

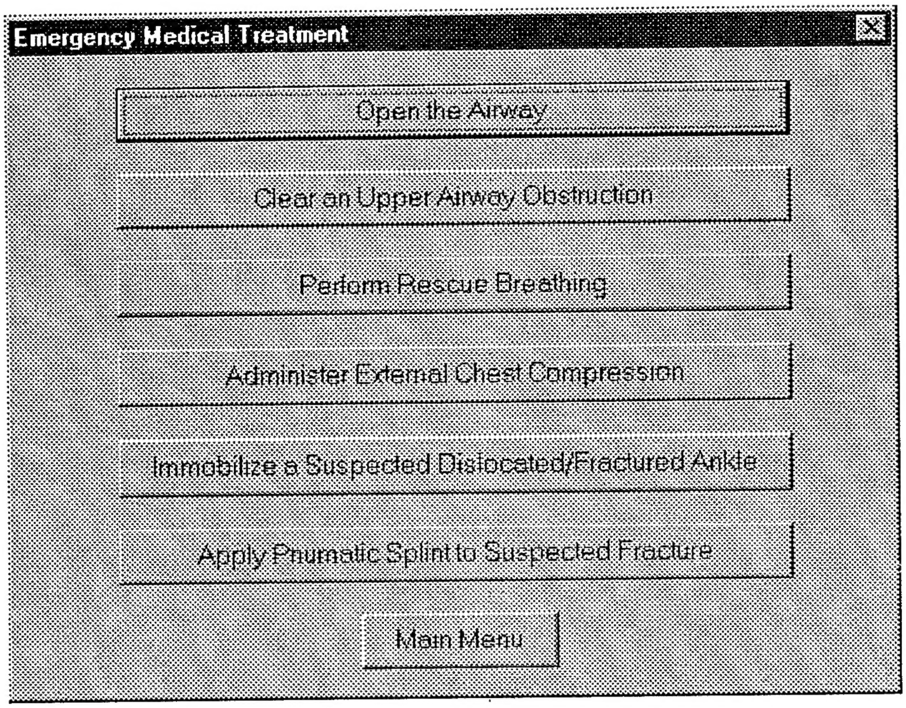


Figure 2.2.1.6-1 SOP Module

The SOP is currently a shell window. When activated from the main menu, the SOP module displays the above information. Time constraints precluded us from implemented full usage. This module will eventually be a hypertext-enabled module that will respond to the user's voice and display emergency medical treatment options for several afflictions. Currently, when the user says "airway" CAMA presents a window that informs the user that this module is not yet implemented. Under a subsequent effort, this request would present stored medical treatment procedures matching the valid syntax, e.g., Opening Airways, or Clearing An Upper Airway Obstruction. Where applicable, the procedures will have additional hypertexed words that the user could enunciate to take him to related topics.

2.2.1.7 Vital Signs

The Vital Signs window is shown in Figure 2.2.1.7-1. This date- and time-stamped module is integrated to the non-invasive sensors and displays the parsed data in the appropriate fields. In addition, the user can enter limited information in the Blood Pressure and Skin Color fields. To enter information in the Blood Pressure field, the user says "Blood Pressure" and the cursor will appear in the BP box. The user would say for example "one eight zero over seven eight" to enter 180/78 in the blood pressure field. If

an error is made, the user can tell the computer to back up by saying "back". The complexion state is a check-box field and the user merely says "normal", "pale", or "jaundiced" for a check to appear in the appropriate area.

Once completed, the user can say "record" to save the data, or "main menu" to return to the main menu.

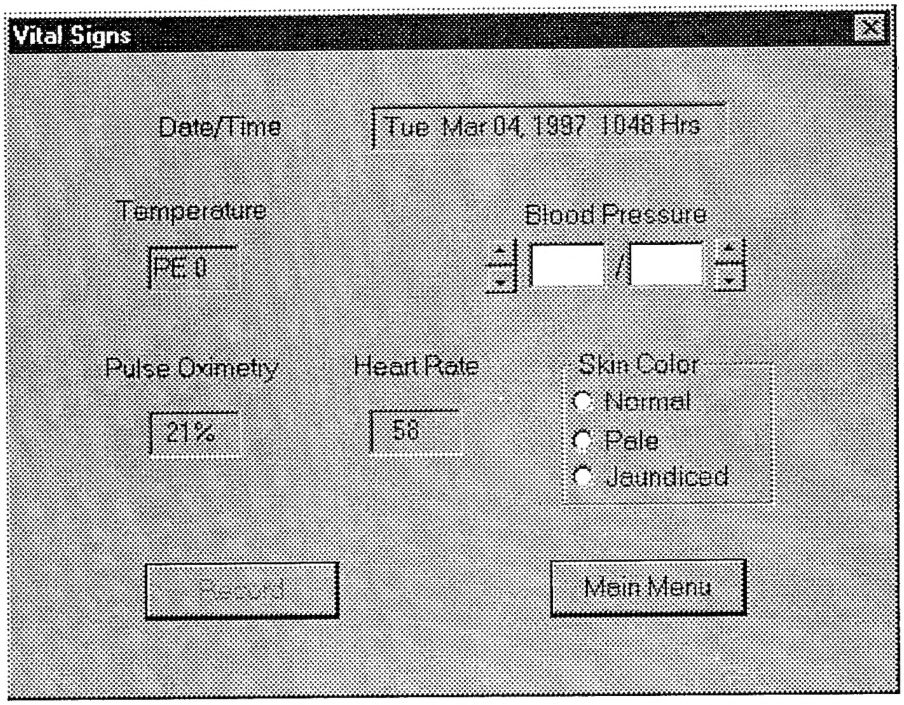


Figure 2.2.1.7-1 Vital Signs Module

2.2.1.8 Patient Data

The Patient Data window is shown in Figure 2.2.1.8-1. This module is an alphabetical-oriented window that displays recent test results. Patient data is listed as follows:

Name	Date	Time	Temp	SPO2	Heart	BP	Complexion
Franklin, Benjamin	Feb05,1997	0920	CE-12	20%	66	120:84	P

Note: Temperature appears as "CE-12" because the sensor was not plugged into the system at the time the data was recorded.

The user can return to the main menu by saying "ok".

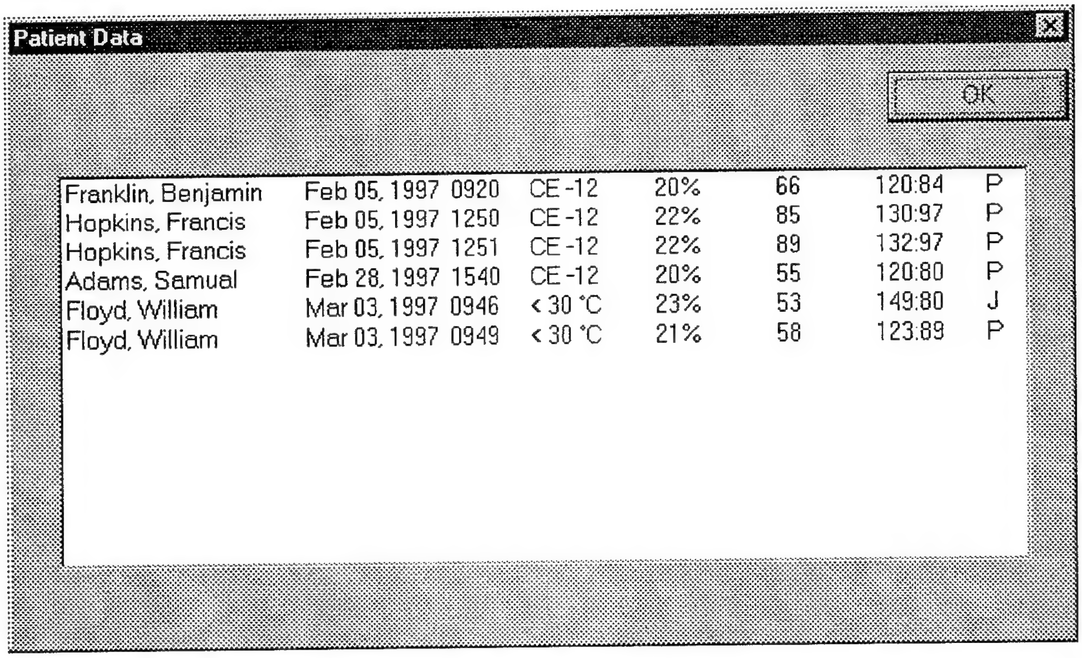


Figure 2.2.1.8-1 Patient Data Module

2.2.1.9 Exit

The Exit window is shown in Figure 2.2.1.9-1. When activated, CAMA asks the user "Do you really want to quit?". A "no" response will return the user to the main menu; a "yes" response will exit the program and return the user to the desktop.

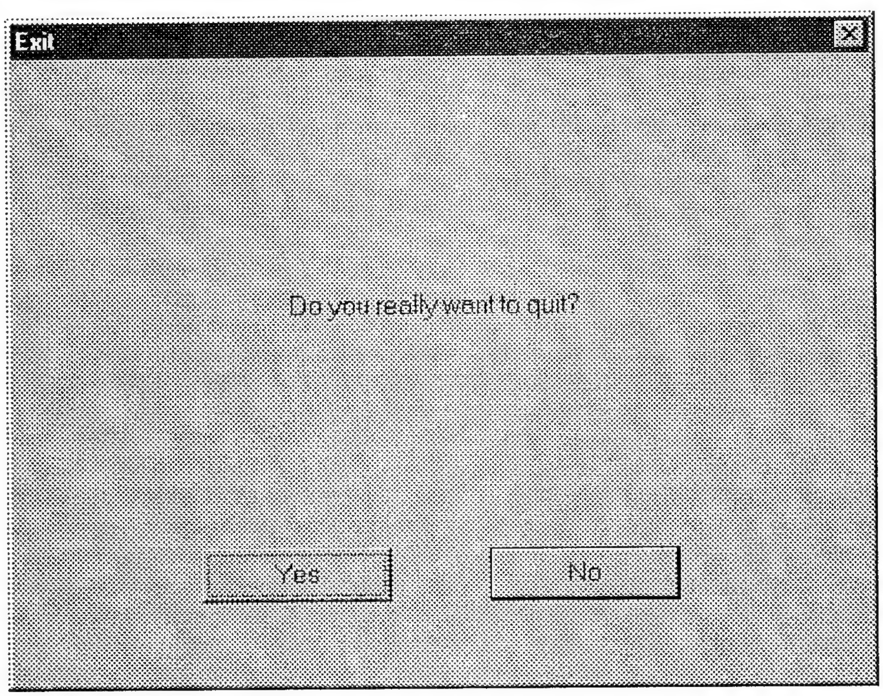


Figure 2.2.1.9-1 Exit Module

2.3 Voice Recognition Module

2.3.1 Research

UTRS researched the following voice recognition products (VRPs):

- Dragon Dictate - Power Edition
- IBM - Voice Type Application Factory
- Kurzweil Applied Intelligence - VOICE
- Lernout & Hauspie Speech Products - asr1500/M

Our research into the above VRPs was not all encompassing. What we were searching for was a product that would satisfy our criteria to demonstrate the feasibility and functionality of the proposed CAMA system. Our VRP checklist included the following criteria:

- Voice Recognition Accuracy
- Voice Recognition Type (Command & Control versus Dictation)
- Voice Synthesis Capability
- Speaker Independence
- Application Specific Contexts and Dictionaries
- Price

Some of the features of these VRPs have changed since the start of this effort, however, at the time we were researching these products, they retained the following qualities:

	Dragon	IBM	Kurzweil	L&H
Accuracy	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Type	Dictation	Command/Ctrl	Dictation	Command/Ctrl
Synthesis	No	No	No	Yes
Speaker Ind.	Yes	Yes	Yes	Yes
Contexts/Dict.	Yes	Yes	Yes	Yes
Price	$1,700	$1,000	$595	$590

"Satisfactory accuracy" was defined as 80% or better "out of the box". Due to time constraints, we were also looking for a VRP that retained the following subjective characteristics:

- A short idiosyncratic learning curve;
- Rapid prototyping and integration capability;
- Available customer support;
- Customization capability that did not require OEM intervention.

After reviewing the specifications for each VRP, we conducted voice interviews with each vendor, ultimately deciding to purchase the L&H VRP. In addition to cost, L&H offered voice synthesis capabilities (text to speech), a Command and Control methodology, and an innovative Lextool Vocabulary Builder that allowed us to add vocabularies to our speech recognition application via keyboard entry or text-file download.

2.3.2 Work Carried Out

The L&H asr1500/M Automatic Speech Recognition (ASR) Software Development Kit (SDK) is a phonetic speech recognition search engine with optimization for commonly used words. The SDK enabled us to utilize C/C++, Visual Basic, and other programming languages to incorporate speech recognition functionality into our CAMA application under the Windows95 operating system.

L&H uses a callback method of notification when sound occurs. That is, one tells a routine in the L&H-supplied DLL what routine in the CAMA software it should call. When that routine is called, it assimilates the information and responds with the appropriate action. Of course, the callback routine needs to know something about what is going on in the CAMA application, i.e., where the user is, and what the valid responses are.

We created our own DLL (*lnhdll*) that contains the callback routine and utilities that the CAMA application must call to control the callback routine. The callback routine responds when it recognizes a particular word. For example, when the CAMA application displays a dialog box with *yes* and *no* buttons, just prior to displaying the box it calls a routine in our *lnhdll* to indicate that the words *yes* and *no* should be recognized. When it recognizes a valid response, the callback routine activates the appropriate Windows95 command as if the user had clicked the mouse in the *yes* or, if appropriate, the *no* button. When the dialog box is to be removed from the screen, these links between speech and Windows action must also be removed, so a routine is provided in the *lnhdll* to remove the link.

2.3.2.1 Auxiliary Work Carried Out

UTRS had been selected as a beta developer for the IBM VoiceType3 VRP many months before the start of this STTR effort. IBM's previous product, Voice Type Application Factory (VTAF) was scheduled to be discontinued without subsequent support. VoiceType3 was being marketed as a hybrid VRP that combined dictation *and* command and control functionality. It was scheduled to be released around the time of this STTR. However, upon its release and its subsequent shipment to our office, we discovered substantial software anomalies that precluded further use until the bugs were rectified by the manufacturer. By the time the rectified version was released, we were four months into the STTR and time constraints precluded the option of using the new VRP. However, after developing the CAMA application using the L&H VRP and integrating it

into the C++ screens, we decided to devote some time with the IBM product integrated into Delphi screens.

2.3.3 Results Obtained

We were able to use the L&H SDK to adequately demonstrate the CAMA application with passable accuracy; however, the speech recognition engine did not always operate in a consistent manner. For example, speech recognition was excellent one day and poor the next (under identical external environments). Thresholds and input gains were kept at the same levels, and peripherals (e.g. microphone and speakers) and testing environment were unchanged. We concluded that the user's speech pattern (i.e. volume and/or articulation) in conjunction to the *placement* of the microphone (i.e. the distance from the user's mouth to the microphone and/or the angle of placement) were the determining factor(s).

The L&H SDK is 32 bit code which enables it to run efficiently. And, as part of the CAMA application, we intended to integrate a Global Positioning System (GPS) PC Card into the system to enable field personnel to take a fix on their location. However, the GPS Application Programming Interface (API) was written in 16 bit code. Since the two APIs could not communicate with each other, it was necessary to write a *thunking* layer that allowed the 32 bit application to communicate with the 16 bit application. The *thunk* is written in *thunk* script and interpreted by a *thunk* compiler. The output of the *thunk* compiler (which is part of a large tool package sold by Microsoft) is assembly language source code which is subsequently assembled and linked in the usual fashion. Although not a simple feat, the *thunking* layer proved successful and the GPS application can now be activated via voice.

An impediment to simple interaction with the application is found when the application plays a wave file. The L&H speech engine controls the audio output, therefore when the application calls a wave file, the engine must be disabled, and then re-enabled when the wave file finishes. This precludes permitting the user to proceed without listening to the entire wave file.

2.4 Electronic Breadboard (EB)

2.4.1 Research

In order for the non-invasive sensors to interface to The Wearable™ (or any handheld, laptop, or portable computer) it was necessary to develop an interface device. At the outset of this effort, we proposed to design and develop a generic interface adapter that would function through the use of a PC card. (Initially we included a caveat that it would probably not be portable under a Phase I research effort.)

The objective of the EB was to enable portable computers with PC slots to be able to function as vital signs computers. Currently, many medical product companies such as

IVAC, Datascope, and Nellcore manufacture proprietary devices that measure heart rate, blood pressure, temperature, etc. Our objective was to develop an electronic breadboard that would take analog signals from these devices and convert their data to digital signals. The EB would in turn, parse the digital vital sign information into the Vital Sign module of the CAMA system. It would be accomplished by writing a dynamic linked library (DLL) which provides the common interface from which most programming languages can interface.

In order to design a dynamically configurable interface to a suite of medical sensors, several options were considered. Based on size constraints and ease of use in the field, a Type II PC Card was selected as the best option to meet design criteria. PC Cards allow plug and play type hardware under the Windows '95 operating system. This is realized through structured abstraction layers defined by the PCMCIA 2.0 standards (Socket Services, Card Services, Client Device Drivers). Additional abstraction is provided by the '95 environment (Configuration Manager functions, Bus Enumerator, Virtual Device Drivers). Prototyping PC cards are commercially available and also reduce NRE costs and development time.

Research into circuit logic design was performed in order to produce an interface card which could be reconfigurable in the field and provide the required functionality. It was essential that the prototype be generic in design such that it would be capable of interfacing with a variety of sensors. The solution to this requirement was a programmable logic circuit which could be downloaded dynamically in the field. This gave us the flexibility necessary to design the prototype.

2.4.2 Work Carried Out

UTRS designed the hardware/software and electronic specifications for the EB and submitted them to our subcontractor, New Mexico State University's Physical Science Laboratory (NMSU PSL). PSL performed the technical research required to fabricate the EB. PSL ordered the requisite materials, staffed the production team, fabricated the EB, and remained in close communication with UTRS during the contract to discuss priorities, design trade-offs, and technical updates.

2.4.2.1 Hardware

The architecture of the EB consists of two Application Specific Integrated Chip (ASIC) devices and tri-state buffers for addressing of the card. It uses six Analog to Digital (A/D) converters with 12 bits of resolution. The cabling is a standard tri-cable pigtail which is connected to the header of the PC Card. The hardware design was driven by the fact that a portion of the control logic would need to be dynamic. An Altera ELPD was selected to provide this capability. The device drivers load chip logic after the card is inserted and identified by the system. The hardware consists of the following:

- Accurite HeadstartCard prototyping card
- Altera EPF8282ATC100-3 EPLD
- Maxium MAX196ACAI 12-bit DAS
- 74HC138M 3 to 8 line decoder IC
- 74HC574WM octal D flip-flop IC

74HC138 and 74HC574 are used to load the Altera Electronically Programmable Logic Device (EPLD) via an I/O port from the Zilog interface IC on the HeadstartCard. A portion of the EPLD is SRAM based and must be loaded after power is applied. The EPLD controls the DAS and interfaces the DAS data to the PC-CARD interface. The MAX196, is a multirange, single +5 volt, 12 bit DAS with a 12-bit bus interface. There are six (6) analog input channels. Only three (3) are used in this application. Each analog input has software selectable input ranges of ±10 volts, ±5 volts, 0 to +10 volts and 0 to +5 volts. The CAMA application uses 0 to +5 volts.

Interface to the sensor suite is through a 3-gang connector interface. This interface provides auto identification of the attached sensors produced by pull-up resistors in the sensor interface gang (4 per port) and a sensor-unique line resistor in the sensor headshell.

2.4.2.2 Software

The software design consists of a device driver and application-specific software development. The system had to recognize the interface, dynamically configure to it, recognize the attached sensor, and provide a simple interface for application programs to retrieve sensor data. For this effort, we decided to make the application/driver interface polled rather than interrupt driven so that the sensor subsystem would not use an excessive amount of system resources.

The Altera EPLD is programmed during the first call to the PCMCIA card by an application program. The driver determines if the Altera's setup has been modified since the last insertion; if not, it downloads the TTF file through the Zilog chip set into the Altera. Since the tuple (data structure used to describe the PC Card functionality) information permits multiple card configurations, dynamic loading functionality is inherent in the card design. Currently the card configuration tuple describes the card as both an IO port and as a memory port. The device driver uses the IO port as the prototype version contains no on-board memory (the device pseudo-registers are flip-flop groups on the EPLD).

The device load code is contained in the Altera Setup module in the device driver. This software emulates the required Altera signal conventions and timing. It drives the clock, data lines, etc. Once the EPLD is set, the system operates in a normal manner.

The CAMA PC Card is designed to sample each of three possible separate instruments via the Altera Analog to Digital channels. Each instrument's connector is

keyed with an instrument code that is passed along with the sample by using 4 data bits (the sample is collected from a 12 bit A/D and we used the other 4 bits of the 16 bit register to ID the instrument). When the connector is plugged into the CAMA PC Card, the A to D samples the instrument code and data values. The driver reads these values, parses the code and value portions for each of three channels and returns this data to the Win32 application which called the virtual device driver.

2.4.3 Results Obtained

The sensor subsystem successfully obtained thermister data and auto identified pulse/oximetry sensors. It was integrated into the CAMA system and provides a basis to continue development of a more robust, fully automated medical field system.

The prototype card and associated software were tested in continuous sample mode over a 72 hour period without failure. Several hundred sensor connect/disconnects were performed to verify auto-identification, and the insertion of the PC card into its interface slot was tested to verify card setup functionality.

The results of these tests proves the concept of the prototype, namely that an economic and rugged sensor interface can be developed which will assist in the automation and efficacy of the field medic's duties.

2.5 Non-Invasive Sensors

2.5.1 Research

UTRS proposed to integrate two (2) non-invasive sensors into the CAMA system. Over the years, we have maintained professional relationships with several medical product companies, and upon commencement of this STTR, we contacted IVAC Medical Systems, Nellcore Puritan Bennett (NPB), and Datascope, Inc. to explore the options of obtaining an electronic thermometer and a pulse oximetery sensor to integrate into the CAMA system. As might be expected, our overture was met with caution, if not with suspicion, but after many phone conversations, meetings, written correspondence, and non-disclosure agreements, we were able to obtain the electronic thermometer apparatus, as well as the external hardware required for pulse oximetery measurements.

2.5.2 Work Carried Out

UTRS obtained an electronic temperature sensor from Datascope, Inc. and associated cabling. In addition we were able to obtain a pulse oximetery sensor from Datascope; however, this type of device requires the use of Datascope's proprietary algorithms as well as proprietary hardware necessary for pre-processing of data. We were unable to secure a satisfactory agreement with Datascope for this Phase I effort to obtain

the algorithms and pre-processing hardware, therefore we simulated the pulse oximetery data and parsed the information into the CAMA Vital Signs module.

The sensor's cables were truncated and fitted into a standard RS232 wiring harness to mate with a similarly outfitted ending to the PC Card trunk cable.

2.5.3 Results Obtained

The temperature sensor operates successfully and parses the collected data into the CAMA Vital Signs module. As previously stated, the pulse oximetery sensor parses simulated data into the same module.

2.6 Head Mounted Display

2.6.1 Research

HMD designs currently use a number of display technologies to provide an image to the user. The most commonly used displays in commercially available systems are CRT and LCD, although there are numerous other display technologies under active development. The following is a brief overview of the current status of these technologies relative to their use in HMDs.

2.6.1.1 Cathode Ray Tube (CRT)

CRT technology is one of the primary display sources utilized in visual out-the-window simulation. The use of CRT monitor or projection type displays provides for the high brightness and resolution required for high fidelity simulations. In the area of HMDs, CRTs currently provide the highest commercially available display resolution. Today's technology provides small (1-1.5 inch) CRT displays that can be mounted on the head to provide higher brightness and resolution than other display technologies. Separate CRTs are used to provide an image that is projected through specially designed optics to provide an image to each eye and in some cases, two CRTs are dedicated to each eye with one providing a lower resolution background image and the other providing a high resolution inset that is located in the center of the field of view.

2.6.1.2 Electro-luminescent (EL)

EL technology has been developed in the small (1.3 x 1.1 inches), high resolution format. This technology has applications as both a direct image source and as a backlight for the LCD displays. Small EL displays are currently being developed with a pixel spacing of 24 microns and a resolution of 1280 x 1024 with future plans for a pixel spacing of 12 microns and a resolution of 2048 x 2560. AC EL displays are available with screens up to 1,024 x 768 lines, in an 18-inch diagonal width, and with black layer technology as a contrast enhancement process for commercial applications. This technology is well suited

for harsh military ground vehicles (M1A2, Challenger 2, M109 Howitzer, AGS, etc.). Gray scale of 64 level has been produced with up to 100 lines per inch panels. High resolution EL display for 2nd generation is being developed for the M1A2 system enhancement program (1,316 x 480 pixel, 16:9 aspect ration, 64 gray levels, and 170 lines per inch horizontally). Small size full color EL displays are in low rate production now.

2.6.1.3 Ferro-Electric Liquid Crystal (FLC)

Ferro-electric liquid crystal displays are non-emissive displays that have been researched by several companies in the past few years. As a technology it has some significant improvements over the mainstay of display technologies, because its viewing angle is significantly wider and independent of multiplexing ratio. FLC technology consists of a thin slab of FLC material between a pair of substrates that bear electrodes. The display is based on a spatial light modulator that consists of an array of square pixels organized in rows and columns. Each pixel in the array can be electrically turned on, as opposed to AMLCDs which must use three pixels and mix their light to make an equivalent range of colors (triads). FLC-based technology as it relates to HMDs is a very recent development and is currently available only in kit form.

2.6.1.4 Liquid Crystal Displays (LCD)

LCD technology has made great advances in the area of high resolution. Small (1.3 x 1,1 inches) LCD-based displays are currently integrated into numerous HMD designs. Monochrome resolution of 640 x 480 displays have been demonstrated and there are plans in the very near future to provide 1280 x 1024 and 2560 x 2048 resolution displays. LCDs are categorized into two types; passive-matrix (PMLCD) and active matrix (AMLCD).

2.6.1.4.1 Passive Matrix Liquid Crystal

Currently, most PMLCDs are operated in the transmissive mode with backlight. The backlight consist of fluorescent tubes with a diffuser for producing a uniform luminance over the display surface. Color LCDs require more power than monochrome displays. To produce color in liquid-crystal technologies, one of the substrates has to have red-green-blue (RGB) striped color filters on it. However, even with their higher power requirement over monochrome, the color LCDs consume less power than any of the other competing color emissive display technologies. The other two parameters limiting the application of PMLCDs are the response time and the viewing angle. Recent developments in material and cell construction have improved contrast ratio and viewing angle characteristics, and has resulted in slower response time for liquid-materials. The display size of this technology is limited (because it is refreshed technology without memory) by the contrast ratio and viewing angle requirement which will always decrease with an increase in the number of multiplexed lines. In spite of these limitations, the STN PMLCDs still remain attractive because they have a lower cost and a large supplier base compared to the alternatives.

2.6.1.4.2 Active Matrix Liquid Crystal Displays

AMLCD technologies are not limited as PMLCDs are by the dependence of viewing angle and contrast ratio on the number of multiplexed lines. This limitation is removed by adding a semiconductor device, e.g., a thin-film-transistor (TFT), or thin-film-diode (TFD), at every pixel, which provides the charge storage (memory). Thus, the display panel matrix-addressing signals are applied directly to the semiconductor device and through it to the liquid-crystal, resulting in higher contrast ratios and wider viewing angles for the AMLCDs. The TFT AMLCD technology promises good visual/electrical characteristics and low power, and has recently started appearing in high price models. Even with the improvement that this technology has demonstrated over the PMLCD technology, it still has some parameters that need to be improved further, most important of which is the narrow viewing angle for the lowest contrast gray levels, which also results in a change of color at wide viewing angles. The response time and high temperature performance also need to be improved.

2.6.1.5 Microtip Field Emissive Displays

Microtip field emissive display (MFED) technology has been around for over a decade with several companies demonstrating impressive prototypes both in monochrome and in color displays with 6 inch diagonals (not yet in HMD form factor). In addition to its response time, viewing angle, and average power advantages (compared to TFT and AMLCD), it also promises a lower manufacturing cost. Also attractive is the prospect of doing all of the logical functions with the same basic technology on the substrate. Its major drawbacks include a requirement for high voltage drive circuits (80 volts), and for new low voltage phosphor materials. This rivals the objective of AMLCD developers who would like to do the line data shifting, column drivers, and row multiplexing drivers with TFTs fabricated on the same substrate as the display.

2.6.1.6 Plasma

Plasma technology is currently being applied to flat panel displays but not in the sizes that are required for HMD applications. DC plasma products from Japan primarily dominate plasma display usage in portable computers mainly due to cost. The recent introduction of black background DC plasma technology has provided the larger contrast ratio needed for 16 gray levels and for color. This technology has been demonstrated with up to 125 lines per inch resolution in the monochrome implementation. AC plasma displays have not found as wide a usage compared to the DC plasma displays, primarily due to their high price. However, recent developments in AC plasma promise to achieve costs competitive with that of DC plasma. The AC plasma technology provides higher luminance and higher contrast ratios at lower power, compared to DC plasma technology. AC plasma displays also have memory which makes the luminance independent of the number of multiplexed lines. Thus, there is no limitation on the panel size based on luminance as there is with DC plasma technology and other refresh technologies. AC

plasma panels have been implemented with 64 gray levels. Full color has been demonstrated in both AC and DC technologies, but not at high resolution.

2.6.1.7 Display Technologies

The following table illustrates the latest display technologies, along with their pros, cons, and structural phenomena.

DISPLAY TECHNOLOGIES			
TECHNOLOGY	**ADVANTAGES**	**PROBLEM AREAS**	**PHENOMENA**
AMLCD Active Matrix Liquid Crystal Display	Quality Image Full Color Video Speed Bright and Dimmable	High Cost Limited Viewing Angle Backlight	Twisted Nematic Mode of Liquid Crystal Filter for Color
FLC Ferro-electric Liquid Crystal	Quality Image Full Color High Resolution Low Power	High Cost Still unavailable	Spatial Light Modulator External Light Source
LED Light Emitting Diode	Long Life High Efficiency in Color	Small and Medium Size Limited Blue Available	Solid State Diode which Emits Visible Photons at Junction Transition
ELD Electroluminescense Display (AC Thin Film)	Fast Response Time No Flicker or Smear Wide Viewing Angle	Low Efficiency Phosphors Complicate Full Color Design	Phosphor with Dialectric in Triple Layer Existed with AC High Electric Field
PDP Plasma Display Panel (DC and AC)	Large Size Bright Fast Response Wide Viewing	Low Efficiency Phosphors Complicated Full Color Design	Classical Gas Discharge with Light from Positive Column and Phosphors
STN LCD Super Twisted Nematic Liquid Crystal Display (Passive Matrix)	Low Cost Flexible in Application Color (CSTN LCD)	Slow Response Small Size	Birefringence with Polarizer and Analyzer Retarder, Compensating Film Used to get White
TN LCD Twisted Matrix Liquid Crystal Display (Passive Matrix)	Low Cost Simple Construction	Slow Response Small Size	Birefringence with Polarizer and Analyzer Retarder, Compensating Film Used to get White
FED Field Emitter Display (Flat CRT)	Low Cost Expectation	Still in Development	Electrons Emitted from Tips and Accelerated Similar to VFD

2.6.1.7 Cost Drivers For Display Technology

There are at least four factors which affect cost in an HMD. These factors distinguish low cost display systems from moderate or high cost display systems. These display parameters cannot be ignored because they affect the overall visual performance and quality of the scene that the eye perceives. Degradation in any one of these parameters will impact performance. A brief discussion of each is presented below.

2.6.1.7.1 Resolution

Resolution relates not only to the number of horizontal and vertical pixels displayed but it is also a function of lens type, spot size (electrostatic or electromagnetic focus if using CRT), bandwidth and contrast (Modulation Transfer Function). The higher the resolution, the more the projection system will cost.

2.6.1.7.2 Brightness

Brightness is a function of the type of light source (arc-lamp or CRT based), lens type and coating, folded optics, field-of-view and screen type. If a high brightness is needed, then cost will increase.

2.6.1.7.3 Geometric Distortion Correction

Distortion Correction is the ability of the display system to correct for keystoning and barrel distortion introduced when projecting off-axis and/or on a curved screen. Depending on the size and curvature of the screen, distortion correction will increase the cost of the projection system.

2.6.1.7.4 Field Of-View

The area projected to the viewer will directly affect the brightness, contrast and resolution. If higher brightness/contrast/re solution and a large field-of-view is needed (more projectors), then cost will increase.

2.6.1.7.5 HMD Vendors and Products

Throughout this effort, UTRS has compiled a list of HMD vendors and their products. Table 2.6.1.7.5-1 illustrates the diversity that is currently available and the technology that is being utilized.

VENDOR	PRODUCT	TYPE	RESOLUTION	FOV	PRICE	MISC.
Astounding Tech.	Video Visor	AMLCD	428x244	30x22.5	$795	14 oz.
Astounding Tech.	Video Visor	Dual LCD	215x162	30x22.5	$795	16 oz.
CAE Elect. Ltd.	Atari IVR	Single LCD	209x167	50x40	$200	Interfaces w/ Atari
CAE Elect. Ltd.	FiberOptic HMD	CRT Proj./fiber	not available	120x55	not available	4.5 lbs.
DisplayTech.	ChronoColor	FLC	640x480	20degrees diag.	$8,500	kit form
Division	d'Visor	AMLCD	345x259	105x41	$6,900	80 oz.
FakeSpace	BOOMD3M	Dual CRT	1280x1024	140x90	$25.000	2DOF
FakeSpace	FS2	Dual CRT	1280x1024	140x90	$95,000	6DOF
FakeSpace	MedView	Dual CRT	1280x960	30x30	$95,000	6DOF
FakeSpace	PIVOT	Dual CRT	1280x1024	140x90	$45.000	
Forte Tech.	VFX-1	Dual LCD	278x204	48x35	$995	16-24oz
General Reality	CyberEye CE-200N	Dual AMLCD	789x230	22.5x16.8	$1,895	14oz.
General Reality	CyberEye CE-200W	Dual AMLCD	789x230	35x26	$1,995	14oz.
General Reality	CyberEye ACE-200N	Dual AMLCD	789x230	35x26	$2,595	16oz.
Hughes Training	ClearVue	Mono CRT w/ LC fltr	1280x1024	80x40	$95,000	3lbs., 5oz.
Kaiser Elect. Opt.	Full Immersion	6 LCDs per eye	1153x300	155x40	n/a	36oz
Kaiser Elect. Opt.	SIM EYE 40	Dual CRT	1280x1024	60x40	$145,000	4.5lbs.
Kaiser Elect. Opt.	SIM EYE 60	Field Seq. CRT	1280x1024	100x60	$165,000	5.2lbs
Kaiser Elect. Opt.	VIM 1000HRpv	4 AMLCDs	800x225	100x30	$7,995	26oz.
Kaiser Elect. Opt.	VIM 500pv	Dual LCD	237x225	40x30	$3,495	
Kaiser Elect. Opt.	VIM 3/EYE	3 LCDs per eye	1380x640	116x30	n/a	
Kopin	VU-Port	Mono LCD	640x480	26x19	$3,000	10oz.
LEEP Systems	CyberFace2	1LCD Diverg. Axis	389x119	140x110	$10,500	32oz.
LEEP Systems	CyberFace3	1LCD, head-coupled	480x120	80x60	$17,105	3DOF, earphones
LEEP Systems	CyberFace4	1LCD, head-coupled	640x480	80x60	$18,400	3DOF, earphones
LEEP Systems	CyberFace5	Quad LCD	1170x202	140x110	$45,000	
Liquid Image	MRG2.2	LCD	720x240	84x65	$3,495	4lbs.
Liquid Image	MRG3C	LCD	756x556	84x65	$5,500	4lbs.
Liquid Image	MRG4	LCD	479x234	61x46	$2,199	2lbs.
Liquid Image	MRG5	Dual LCD	480x256	50xn/d	n/a	1.2lbs
Nissho Elect.	NewHRX	Dual 3" LCD	920x480	110x77	$80,000	3lbs.
nVision	Datavisor 9ci	Dual CRT	1280x1024	50x37	$56,000	3.5lbs
OIP	HOPROS	Mono CRT	640x480	20x20	$3,000	14oz.; see through
OIP	HOPROS	Dual CRT	1000x300	20x20	$7,000 - Stereo	14oz.; see through

TABLE 2.6.1.7.5-1 HMD Vendors and Products

RPI-ATG	High View 180	Dual AMLCD	827x428	25x19	$1,850	4oz.
RPI-ATG	HMD Model 975B	Dual LCD	316x230	55x36	$9,975	33oz.
RPI-ATG	HMS-EYE2	Dual LCD	316x230	55x36	$1,850	16oz.
RPI-ATG	HMS Micro Mdl900	Dual LCD	473x218	65x40	$3,500	4oz.
RPI-ATG	CheckMate 100	Dual AMLCD	2481x684	120x40	$41,050	19oz.
RPI-ATG	Silicon Window 3C	Dual CRT	1280x1024	60x65	$59,000	Desk-mounted
Seattle Sight	MARK I	Mono LCD	640x480	60x65	$2,500	10oz
Shimadzu Corp.	STV-01	Dual LCD	600x480	60x36	$30,770	
VictorMaxx	CyberMaxx	Dual Color AMLCD	267x225	56x42	$899	3DOF, 14oz.
VictorMaxx	CyberMaxx2	Dual Color LCD			$499	1.3lbs.
Virtual I/O	i-glasses!	Dual LCDs	789x230	25x19	$599	8oz. 3DOF
Virtual I/O	i-glasses! ProTec	AMLCD TFT-LCD	640x480	42 degrees diag	$6,000	12.5oz
Virtuality	Visette Pro	Dual TFT AMLCD	640x480	60x46.8	$5,950	23oz.
Virtual Reality	Color HMD133	Field Seq. CRT	1280x960	40x30	$40,000	3lbs.
Virtual Research	VR4	Dual AMLCD	724x230	48x36	$7,900	
Virtual Research	VR4000	Dual LCD	732x230	30x22.5	n/a	
Virtual Research	VR5	Dual CRT	640x480	42.4x31.8	$20,000	2lbs.
Virtual Vision	CMK110				$1,050	
Vista Controls	Vista Vision	Mono AMLCD	640x480	32x24	$12,500	
Vista Controls	See-Thru-Armor	Dual LCD	789x230	32x24	$25,000	5lbs.;2-6DOF

TABLE 2.6.1.7.5-1 HMD Vendors and Products

3.0 SUMMARY

The CAMA system successfully demonstrates the feasibility of effective, mobile, medical treatment and display. Under this six month effort, we were able to research, develop, and integrate many diverse, state-of-the-art computer and medical technologies into a functional prototype. The CAMA prototype, although limited in its functionality, unquestionably demonstrates the future benefits that can be realized in a battlefield or commercial environment from a mobile medical platform.

4.0 FUTURE RESEARCH

UTRS welcomes the opportunity to further the capabilities of the CAMA system. The following is a brief synopsis of the advances that would be accomplished under a Phase II effort.

4.1 CAMA Software

UTRS would complete the CAMA voice recognition application. This would include the interface and content to all referenced modules. The CAMA System would be a comprehensive voice-activated medical application, including robust medical S.O.Ps and Protocol interfaces. We would utilize a high-end commercial-off-the-shelf (COTS) VRP (e.g. Dragon Dictate Professional Series, or IBM VoiceType3) for baseline capabilities, and then modify the system to rapidly display select medical information suitable for field use. This would include hypertexted S.O.Ps, voice-based email transmission and retrieval capabilities, etc. In addition, the CAMA System would be adapted for wireless communication capable of transmission and reception in the field.

By the end of 1998, Motorola has stated that it will have launched 66 Irridium satellites that will enable cellular capability anywhere in the world. (At least four other companies, including Microsoft, Hughes, and Loral intend on launching their own satellite-based telecommunications network by the year 2002. The Microsoft endeavor entails the launching of 840 satellites by itself.) The CAMA system, since it has cellular system capabilities via PC Card, would be able to send and receive vital medical information anywhere in the world. This would result in a very effective telemedecine tool. Furthermore, updating the CAMA system would be as simple as downloading the latest version from a website.

4.2 Electronic Breadboard

UTRS would further the development of the EB to create an intelligent Medical Computer Enhancement (MCE) PC Card that is capable of interfacing to at least 6 non-invasive sensors. The addition of First In First Out (FIFO) processors would enable the Card to perform discreet input/output (I/O). The ramifications of this "intelligence" translates into the following functionality:

- The PC Card would not operate by constantly polling for sensor data. Data thresholds could be set with conditional responses programmed into the computer for respective conditions. A potential scenario would work as follows: a patient is being monitored via non-invasive sensors integrated into the CAMA system. The PC Card is activated because the sensors have surpassed a preset threshold (e.g. heartrate > 100). The system sends a message to a roving field medic via wireless communication. A warning alarm notifies the medic that Patient Jones has exceeded a preset heart monitoring condition. This capability would act as a "force multiplier", yielding higher productivity with less personnel.
- The PC Card would be designed with discreet I/O capabilities; this would enable the computer to send and receive radio frequency (rf) signals. This means that a plethora of automated signal processing commands would be available for the user. For example, a handicapped individual would be able to tell the computer to open a door, or turn on a light (or appliance) and the computer would send the requisite signal. (Of course, the door or appliance would have to be modified with a receiver that would receive the rf signals.)

The PC Card's cabling and connections would be modified for quick access and release. Furthermore, UTRS would research requirements for advanced automated manufacturing to produce the PC Card in large quantities rather than by hand.

4.3 Head Mounted Display

Throughout the Phase I effort, UTRS has researched the current state-of-the-art HMD products and manufacturers. We are in a unique position to design and develop a prototype HMD designed for medical field use. UTRS would design the HMD in-house using our computer-aided design (CAD) workstations. Next, we would solicit bids from at least three HMD manufacturers to build a prototype HMD according to our specifications. Lastly, we would negotiate with the vendors to obtain the best product at the best price.

5.0 CLOSING REMARKS

UTRS would like to thank the Army Research Office for the opportunity to work under the STTR Research Program, as well as the COTR for this effort, Dr. Stephen Bruttig from the Combat Casualty Care Research Program for his professional advice. It has been an enlightening and rewarding experience. If there are any questions regarding the research carried out, or the content of this report, please contact:

Mr. Steven M. George
Director, Northeast Operations
200 Valley Road
Suite 306
Mt. Arlington, NJ 07856
Phone 201-398-8882 - Fax 201-398-8870 - Email 102567.1032@compuserve.com

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